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LETTERS TO THE EDITOR

Dear Editor:

I have read with interest the letter by a Mr. Otto Matty Khodr regarding the device known as a Computer Language Translator. His letter caught my eye immediately because I, like many others, have welcomed the introduction to the industry of the Computer Language Translator as a major advancement in the state of the art.

Mr. Khodr has drawn some semantical conclusions as far-fetched as his spelling of "automatic coder". It is my firm conviction that the space in your excellent publication could be put to far better use than the degradation of such a long needed device.

Mr. Khodr could well profit by a period of study at the Institute of Greater Semantics in Lime Rock, Connecticut. However, I am sure that he would find a perusal of a good standard dictionary a prerequisite for his entrance into the Institute. According to his letter, "language" and "instruction" are synonymous. Does he "language" his subordinates in computer programming?

Lastly, I strongly believe that Mr. Khodr owes an abject apology to the Electronic Engineering Company of California and their staff of very capable engineers who saw the rising need for and developed the Computer Language Translator. Mr. Khodr advises that the Electronic Engineering Company of California stick to their bailiwick. It should be pointed out that they have remained in their bailiwick and there they have applied themselves so well as to invent and produce a timely, long needed, thoroughly capable device which surmounts many of the language and media barriers present in the industry.

Sincerely,

J. GORDON STILLSON
11742 Brookshire Avenue
Garden Grove, California
August 18, 1958

TECHNIQUES DEPARTMENT

Editor's Note:

I have recently been quite disturbed to note that practically all of the new subroutines called to my attention have used series approximations with the higher order terms TRUNCATED. I further shudder to think of all the computing time wasted because everyone unthinkingly uses Hastings' approximations for computers with logical ability, whereas they are primarily designed for computers with only arithmetic ability. A primary use of logical ability in subroutines is to diminish the range which an approximating polynomial is required to service. Then one must use a polynomial tailored to this specific range. This note is concerned with well-known methods which enable anyone to do this most efficiently.

The key to tailor-made polynomials has been given both in Lanczos' latest book and in my paper at the 1955 ACM meeting on "Polynomial Relaxation Coefficients" (Lanczos calls it "telescoping" the coefficients). However, after all this, the computing profession in general does not make good use of this tool. I am therefore printing in this issue, hopefully for your frequent reference, tables of certain useful Tchebysheff coefficients with a brief description and example of how they are used.

Relaxation of polynomial coefficients is a process similar to truncation in the removal of whole terms or portions of coefficients, the distinction being that in relaxation the contribution of the terms removed is approximated and distributed among the lower order terms in a compensatory manner. The error due to relaxation is usually only of a small fraction of the error which truncation would give and thus more high order terms may be removed while still maintaining the necessary precision. In general the technique is used for:

1. Reduction of calculation time and computer storage requirements.
2. Tailoring of rational approximations for specific limitations.
3. Reducing the number of digits in coefficients to take advantage of operations which have variable execution times (in certain computers).

Many approximations used for computers are designed to operate in the interval 0 to L or the symmetric interval $-L$ to $+L$. The tables given here are the Tchebysheff approximations for x^n by polynomials of degree $n-1$, for both of these intervals. Since the special intervals $-.5\pi$ to $+.5\pi$ and $-.25\pi$ to $+.25\pi$ occur for transcendental functions, they are also shown. Tchebysheff polynomials have a constant error bound. For the interval 0 to L, this error occurs at both limits and may thus be determined from the a_0 term. For symmetric intervals, it occurs at $\pm L$; having been evaluated, it is given in the column headed "indicator." For example, Table II shows:

$$Y = 3X^2 \text{ would be replaced by } Y \cong -.375 + 3X.$$

The error for truncation, in the complete removal of the 2nd order term, would be evaluated at $X=1$ and is equal to 3, whereas the relaxation error is equal to .375, or only one-eighth as much.

It is to be noted that Tables I and II are given for $L=1$. The general expressions for the coefficients given in the tables are:

For the interval 0 to L, $$a_i = \frac{(-1)^{(n+i-1)}\, L^{(n-i)}\, 2n\,(n+i-1)!}{2^{2(n-i)}\,(2i)!\,(n-i)!}$$

For the interval $-L$ to $+L$, $$a_i = \frac{(-1)^{\left(\frac{n+i}{2}\right)}\, L^{(n-i)}\, n\left(\frac{n+i}{2}-1\right)!}{2^{(n-i)}\, i!\left(\frac{n-i}{2}\right)!}$$

Thus the first thing to do when preparing for relaxation over a specific interval is to form a special table by multiplying either Table I or Table II by $L^{(n-1)}$. Note that this value is constant for the diagonals. Tables III and IV are useful as test cases to make sure that you understand this technique. Let us now take a sample problem, the relaxation of the Taylor series expansion for the cosine in the interval $-.25\pi$ to $+.25\pi$, which means we use Table III. A table of comparison between relaxation and truncation is necessary to show how many terms one should take before applying the relaxation process.

Term Eliminated	Truncation Error	Relaxation Error
X^6	.00032 59918 87	.00001 01872 46
X^8	.00000 35908 60	.00000 00280 54
X^{10}	.00000 00246 11	.00000 00000 47
X^{12}	.00000 00001 15	.00000 00000 00
X^{14}	.00000 00000 00	.00000 00000 00

This means we may start with the 12th order term if precision to more than 10 decimals is desired. If only 6 decimal precision were desired, relaxation could start with the 8th order term. Actual work would proceed like this:

1.00000 00000 00	−.50000 00000 00 X^2	+.04166 66666 67 X^4	−.00138 88888 89 X^6	+.00002 48015 87 X^8	−.00000 02755 73 X^{10}	+.00000 00020 88 X^{12}
	+ 07	− 1 24	+ 8 58	− 26 81	+ 38 64	− 20 88
					− 02717 09	
− 47	+ 38 42	− 498 23	+ 2261 58	− 4190 09	+ 02717 09	
				+.00002 43798 97		
+ 23	− 11 80	+ 95 62	− 248 01	+ 201 03		
			−.00138 86866 74			
+ 24	− 7 12	+ 30 77	− 33 26			
		+.04166 66293 59				
+ 2	− 25	+ 41				
	−.49999 99988 08					
− 2	+ 8					
1.	−.49999 99988 X^2	+.04166 66294 X^4	−.00138 869 X^6	+.00002 44 X^8 $\cong$ cos X		

Thus the last equation is a suitable approximation for cos X in the given range to a precision of better than (summing the deviations in the constant term, etc.) 1 in the 10th decimal position. Had truncation been used instead of relaxation, an 8th order equation would have yielded a maximum error of 247 in the 10th decimal position, *or* for equivalent precision a 10th order equation would have been necessary.

TABLE I: TCHEBYSHEFF APPROXIMATION IN THE INTERVAL −1 TO 1 OF $X^n \cong \sum_{i=0}^{n-1} a_i X^i$

n	Indicator	a_1	a_3	a_5	a_7	a_9	a_{11}	a_{13}
15	.00006 10352	.00091 55273	.03417 96875–	.36914 0625	1.75781 25–	4.29687 5	5.625–	3.75
13	.00024 41406	.00317 38281–	.08886 71875	.71093 75–	2.4375	4.0625–	3.25	
11	.00097 65625	.01074 21875	.21484 375–	1.20312 5	2.75–	2.75		
9	.00390 625	.03515 625–	.46875	1.6875–	2.25			
7	.01562 5	.10937 5	.875–	1.75				
5	.0625	.3125–	1.25					
3	.25	.75						

n	Indicator	a_0	a_2	a_4	a_6	a_8	a_{10}	a_{12}
14	$= a_0$	.00012 20703	.01196 28906–	.19140 625	1.14843 75–	3.28125	4.8125–	3.5
12		.00048 82813–	.03515 625	.41015 625–	1.75	3.375–	3.	
10		.00195 3125	.09765 625–	.78125	2.1875–	2.5		
8		.00781 25–	.25	1.25–	2.			
6		.03125	.5625–	1.5				
4		.125–	1.					
2		.5						

TABLE II: TCHEBYSHEFF APPROXIMATION IN THE INTERVAL 0 TO 1 OF $X^n \cong \sum_{i=0}^{n-1} a_i X^i$

n	a_0	a_1	a_2	a_3	a_4	a_5	a_6
15	.00000 00019	.00000 08382–	.00006 25849	.00184 41677–	.02845 28732	.26429 55780–	1.60179 13818
14	.00000 00075–	.00000 29206	.00018 98408–	.00485 99243	.06491 47034–	.51931 76270	2.69100 95215–
13	.00000 00298	.00001 00732–	.00056 40984	.01241 01639–	.14183 04443	.96444 70215–	4.20849 60938
12	.00000 01192–	.00003 43323	.00163 65051–	.03054 80957	.29457 09229–	1.67578 125	6.04296 875–
11	.00000 04768	.00011 53946–	.00461 57837	.07200 62256–	.57604 98047	2.68823 24219–	7.82031 25
10	.00000 19073–	.00038 14697	.01258 85010–	.16113 28125	1.04736 32813–	3.91015 625	8.88671 875–
9	.00000 76294	.00123 59619–	.03295 89844	.33837 89063–	1.74023 4375	5.02734 375–	8.53125
8	.00003 05176–	.00390 625	.08203 125–	.65625	2.57812 5–	5.5	6.5–
7	.00012 20703	.01196 28906–	.19140 625	1.14843 75–	3.28125	4.8125–	3.5
6	.00048 82813–	.03515 625	.41015 625–	1.75	3.375–	3.	
5	.00195 3125	.09765 625–	.78125	2.1875–	2.5		
4	.00781 25–	.25	1.25–	2.			
3	.03125	.5625–	1.5				
2	.125–	1.					
1	.5						

n	a_7	a_8	a_9	a_{10}	a_{11}	a_{12}	a_{13}	a_{14}
15	6.65359 49707–	19.51721 19141	41.07543 94531–	62.26171 875	67.38281 25–	50.78125	25.3125–	7.5
14	9.46289 0625	23.18408 20313–	40.00390 625	48.42578 125–	40.25	21.875–	7.	
13	12.30175 78125–	24.60351 5625	33.76953 125–	31.28125	18.6875–	6.5		
12	14.34375	22.71093 75–	23.75	15.75–	6.			
11	14.60937 5–	17.53125	13.0625–	5.5				
10	12.5	10.625–	5.					
9	8.4375–	4.5						
8	4.							

TABLE III: SPECIAL TABLE FOR THE INTERVAL $-\frac{\pi}{4}$ to $\frac{\pi}{4}$

h	Indicator	a_1	a_3	a_5	a_7	a_9	a_{11}	a_{13}
15	.00000 16290	.00003 11121	.00188 29841–	.03296 78524	.25450 22343–	1.00853 74002	2.14033 64729–	2.31318 85315
13	.00001 05635	.00017 48485–	.00793 67052	.10293 20148–	.57211 57616	1.54579 85638–	2.00476 33940	
11	.00006 84997	.00095 93819	.03110 58286–	.28239 04720	1.04638 67201–	1.69633 82564		
9	.00044 41902	.00509 00447–	.11002 22618	.64210 09419–	1.38791 31189			
7	.00288 03761	.02567 18611	.33294 12291–	1.07948 79814				
5	.01867 79593	.11890 75818–	.77106 28438					
3	.12111 82683	.46263 77063						

n	Indicator	a_0	a_2	a_4	a_6	a_8	a_{10}	a_{12}
14	$= a_0$	.00000 41483	.00065 90445–	.01709 44420	.16627 47931–	.77015 58329	1.83117 67602–	2.15897 59627
12		.00002 68998–	.00313 97955	.05938 38547–	.41074 97775	1.28420 18837–	1.85055 08252	
10		.00017 44331	.01413 90130–	.18337 04364	.83235 30728–	1.54212 56877		
8		.00113 11210–	.05867 85396	.47563 03273–	1.23370 05501			
6		.00733 48175	.21403 36473–	.92527 54126				
4		.04756 30327–	.61685 02751					
2		.30842 51375						

TABLE IV: SPECIAL TABLE FOR THE INTERVAL $-\frac{\pi}{2}$ to $\frac{\pi}{2}$

n	Indicator	a_1	a_3	a_5	a_7	a_9	a_{11}	a_{13}
15	.05337 99566	.50974 10371	7.71270 30738–	33.75908 08353	65.15257 19792–	64.54639 35744	34.24538 35666–	9.25275 41260
13	.08653 63261	.71617 95711–	8.12718 61270	26.35059 57783–	36.61540 87186	24.73277 70203–	8.01905 35759	
11	.14028 74079	.98240 71143	7.96309 21308–	18.07299 02008	16.74218 75215–	6.78535 30257		
9	.22742 53794	1.30305 14396–	7.04142 47536	10.27361 50700–	5.55165 24756			
7	.36868 81382	1.64299 91092	5.32705 96659–	4.31795 19255				
5	.59769 46968	1.90252 13093–	3.08425 13753					
3	.96894 61463	1.85055 08252						

n	Indicator	a_0	a_2	a_4	a_6	a_8	a_{10}	a_{12}
14	$= a_0$	.06796 54716	2.69944 60758–	17.50470 85813	42.56634 70264–	49.28997 33034	29.29882 81626–	8.63590 38510
12		.11018 14725–	3.21515 05557	15.20226 67952–	26.28798 57618	20.54723 01400–	7.40220 33008	
10		.17861 94753	3.61958 73322–	11.73570 79294	13.31764 91648–	6.16850 27507		
8		.28956 69866–	3.75542 65374	7.61008 52370–	4.93480 22005			
6		.46942 83172	3.42453 83567–	3.70110 16504				
4		.76100 85237–	2.46740 11003					
2		1.23370 05501						

ERROR ESTIMATION IN RUNGE-KUTTA PROCEDURES

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INTRODUCTION

As is commonly known, the principal criticism of the Runge-Kutta approach to the numerical solution of systems of differential equations has been the non-existence of a satisfactory method for the estimation of the associated truncation error. However, apart from this deficiency, Runge-Kutta procedures have proved highly flexible and their self-starting and stability features render them particularly well adapted to automatic computation. The purpose of this note is to describe a method of error estimation devised by the authors which has been successfully employed in the automatic control of error in Runge-Kutta procedures.

THE METHOD

The basic idea involved in the method is very simple and essentially consists of reversing directions at each step of the advancing solution and recomputing the previous ordinate. Then, as would seem intuitively plausible, by considering the difference between this value of the ordinate and the originally computed value, it is possible to establish an estimate for the truncation error incurred in advancing the solution over that step. Unfortunately, it turns out that this procedure is only applicable to odd-order Runge-Kutta methods. We next proceed to outline the mathematical justification for this method.

We first observe, without proof, that the truncation error associated with a Runge-Kutta formula of the r^{th} order accuracy in progressing from x_n to $x_{n+1}=x_n+h$, in a single step, is of the form

$$Tr=C_{r+1}\cdot h^{r+1}+C_{r+2}\cdot h^{r+2}+C_{r+3}\cdot h^{r+3}+\cdots\cdots \tag{1}$$

where the coefficients C_{r+j} are expressions involving partial derivatives and are independent of the step size h. It is readily seen that if $C_{r+1}\neq 0$, then the term $C_{r+1}\cdot h^{r+1}$ dominates the truncation error as h gets small, i.e.

$$\lim_{h\to 0}\frac{C_{r+2}\cdot h^{r+2}+C_{r+3}\cdot h^{r+3}+\cdots\cdots}{C_{r+1}\cdot h^{r+1}}=0. \tag{2}$$

The error estimation method herein described is based upon the assumption that the coefficient $C_{r+1}\neq 0$ and, indeed, that the term $C_{r+1}\cdot h^{r+1}$ is a good estimate for the truncation error when the step size is small. This is generally the situation. Then, under this assumption, if the true ordinate at x_{n+1} is denoted by Y_{n+1} and the computed ordinate by y_{n+1}, the following approximate relation holds

$$Y_{n+1}\cong y_{n+1}+C_{r+1}\cdot h^{r+1}. \tag{3}$$

See Figure 1

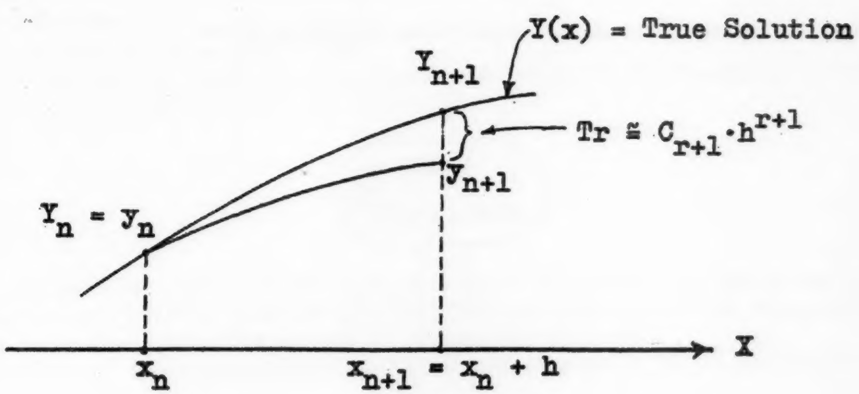

Figure 1

Likewise, letting the true ordinate at x_n be denoted by Y_n and the value obtained by computing in the reverse direction from x_{n+1} by $y_n^{\oplus}$, we have the similar relation

$$Y_n \cong y_n^{\oplus} + C^{\oplus}_{r+1} \cdot (-h)^{r+1}. \tag{4}$$

Next, if we assume that C_n varies slowly with n and is nearly independent of h, it follows that $C_n \cong C^{\oplus}_n$. It is observed that these are the same assumptions as made in the "Extrapolation to Zero Grid Size" method for truncation error estimation [1]. Thus, if we now let y_n denote the original ordinate at x_n computed in the forward direction, it is clear from the above assumption and from equations (3) and (4), that the following approximate formula holds

$$y_n - y^{\oplus}_n \cong C_{r+1} \cdot h^{r+1} + C_{r+1} \cdot (-h)^{r+1}. \tag{5}$$

Hence, if an odd order $(r=3$ or $5)$ Runge-Kutta method is being employed to solve the differential equation, $h^{r+1} = (-h)^{r+1}$ and it follows that

$$y_n - y_n^{\oplus} \cong 2 \cdot C_{r+1} \cdot h^{r+1} \cong 2 \cdot Tr. \tag{6}$$

Therefore,

$$Tr \cong \frac{y_n - y_n^{\oplus}}{2}. \tag{7}$$

However, if an even order $(r=2$ or $4)$ Runge-Kutta procedure is being utilized, then $h^{r+1} = -(-h)^{r+1}$ and it follows that

$$y_n - y_n^{\oplus} \cong 0. \tag{8}$$

From the preceding analysis it is clear that when r is odd the truncation errors incurred in the forward and reverse directions are additive, whereas, they cancel each other when r is even. In the first instance we are enabled to utilize the difference, $y_n - y_n^{\oplus}$, to establish an estimate for the truncation error Tr. When r is even such an estimate for Tr clearly cannot be obtained.

The method employed in practice to effect the automatic control of the error is to compute this estimate for the truncation error at each step of the advancing solution and keep it within pre-determined accuracy bounds by proper adjustment of the step-size. It should be noted that this procedure essentially requires two ordinate evaluations for each step of the solution. This is an improvement over the previously mentioned "Extrapolation to Zero Grid Size" method which requires three ordinate evaluations at each step.

With the purpose in mind of testing this error control scheme the authors have written a routine for the I.B.M. 650 computer employing a Runge-Kutta Third Order Procedure. The routine has been checked out on several test problems deliberately chosen so as to require considerable adjustment of the step size. In each instance it yielded the solution to the designated accuracy.

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[1] F. B. Hildebrand, Introduction To Numerical Analysis, McGraw Hill, 1956, pp. 238–239.

Editor's Note:

This is Part 2 of the report on "The Problem of Programming Communication with Changing Machines". Part 1 was published in the August Issue of the *Communications*.

THE PROBLEM OF PROGRAMMING COMMUNICATION WITH CHANGING MACHINES

A PROPOSED SOLUTION—Part 2

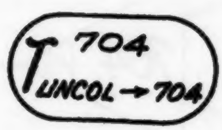
APPENDIX C
USE OF THE UNCOL SYSTEM

The three cases described below illustrate the techniques used:

I. To initiate a new POL in the UNCOL system
II. To convert from one machine to another
III. To revise the UNCOL language (if required).

It is assumed that the customer organization has available:

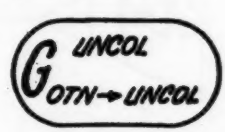
1. A report describing UNCOL, which has been agreed upon as standard by a significant proportion of the computing profession.
2. A machine and its associated language programming system. For this example, let us assume a 704 and SAP.
3. A translator, previously written and tested (on the 704) which translates from UNCOL into (704) ML.



CASE I: Introduction of a new POL

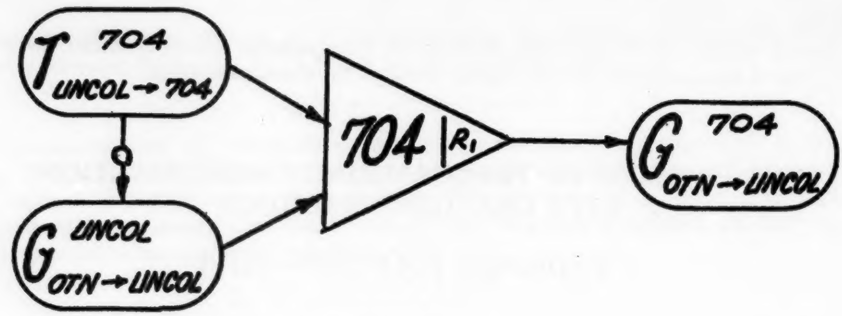
The POL under discussion could be a previously existing one which is new to the customer organization, or a newly formulated one being used for the first time. For this example, let us assume that the POL is a newly formulated one called OMNITRAN. To implement OMNITRAN, the customer organization must have available:

1. A report describing OMNITRAN
2. A generator in UNCOL language (presumably written by the formulator of OMNITRAN) which translates OMNITRAN into UNCOL.



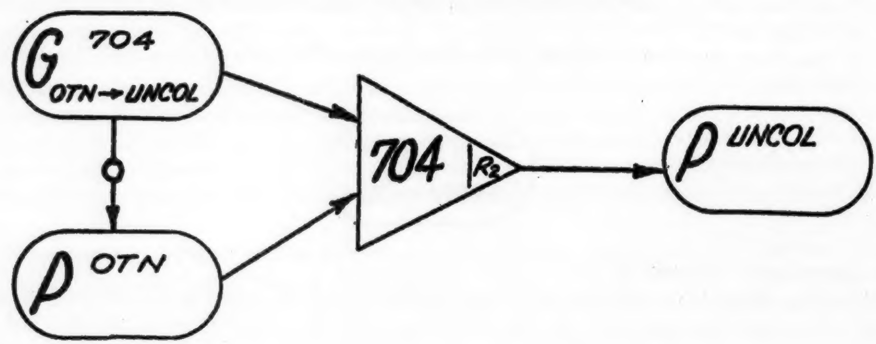
If the 704 was used to check out this generator, a second generator in 704 language has already been produced to translate OMNITRAN into UNCOL. This generator could also be made available to the customer organization, eliminating the need for Machine Run #1, below.

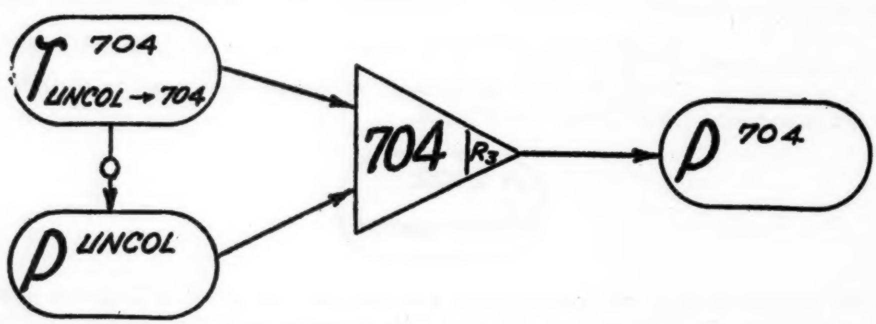
Machine Run #1 is required to produce an OMNITRAN generator in 704 ML from the OMNITRAN generator supplied in UNCOL.



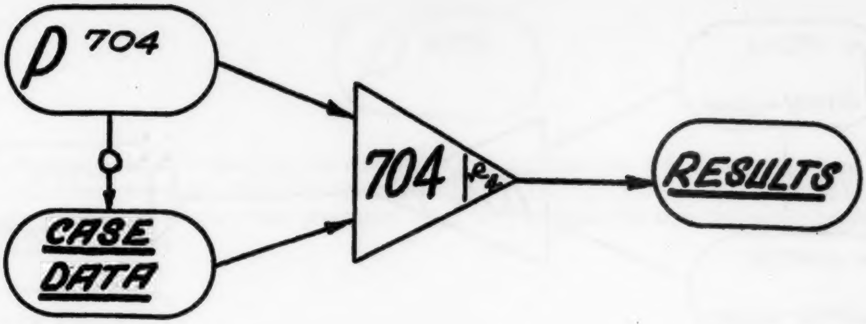
The customer's problems are written in OMNITRAN;

therefore, machine runs 2 and 3 must be accomplished once for each new program written. These runs are analogous to the compiling run on a current compiler. Runs 2 and 3 may be combined if there is no necessity to preserve the problem routines in their UNCOL statement.





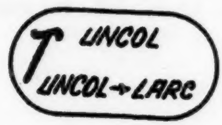
Run #4 becomes the production run of the customer's routine. If a "modify and execute" technique is required, changes can be written in OMNITRAN and runs 2, 3, and 4 can be combined into a single machine run.



CASE II: Conversion to a new machine

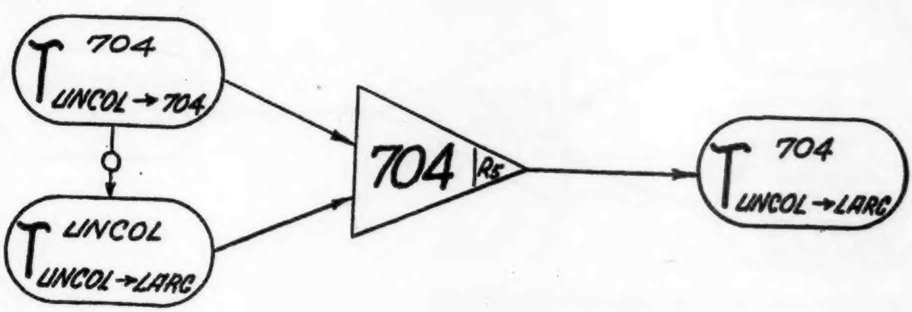
Let us assume that the customer organization is planning to replace its 704 with a LARC. Two items must be available:

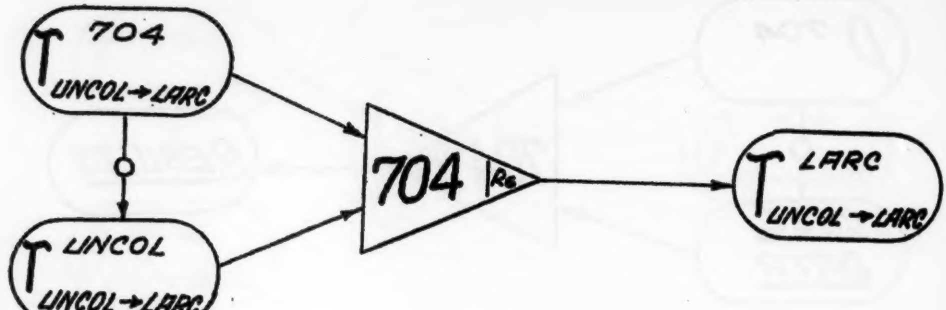
1. A manual describing the LARC ML.
2. A translator (presumably supplied by the LARC manufacturer) written in UNCOL which translates UNCOL into the LARC ML.



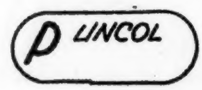
If the LARC was used to check out this translator, a version of the translator in LARC ML has already been produced which could be supplied to the customer or organization, eliminating the need for Run #6, below.

To begin the conversion process, the customer makes Machine Runs #5 and #6 on his existing 704. Note that at the end of Run #6 a program has been produced in LARC ML without programming effort on the part of the customer.

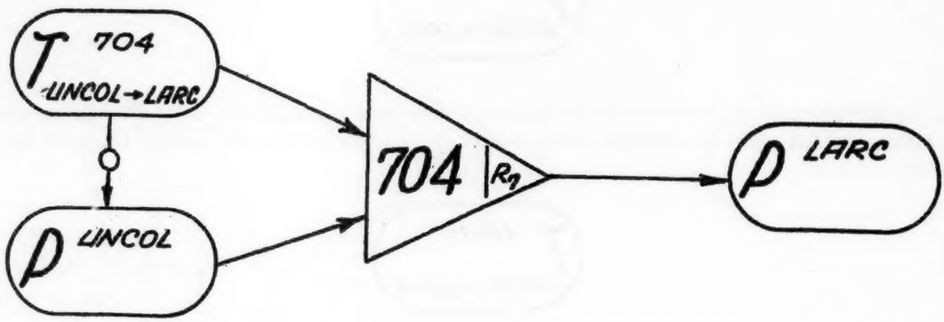




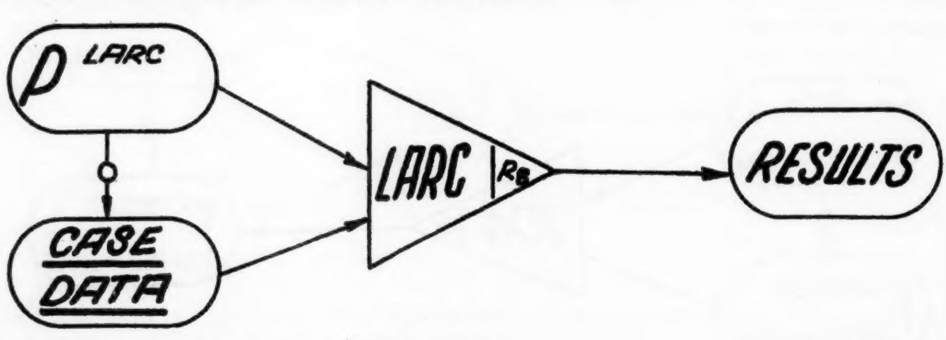
The customer must have available an UNCOL version of each OMNITRAN program to be run on the LARC.



If the UNCOL program decks have not been preserved, they may be recreated by performing Run #2, above. To produce programs in the LARC ML, the customer performs Run #7 on his existing 704 for each program desired.

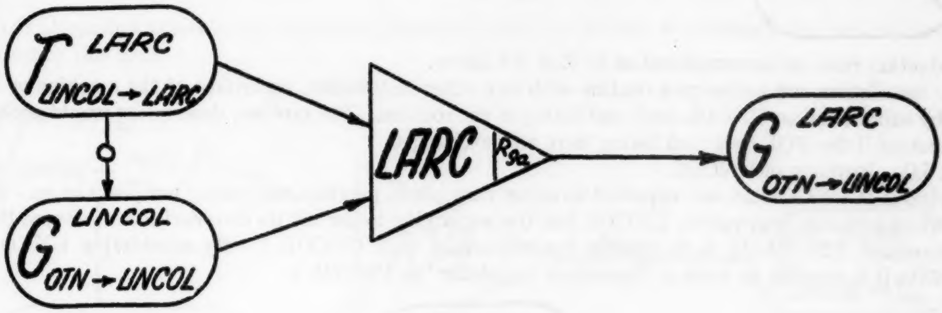


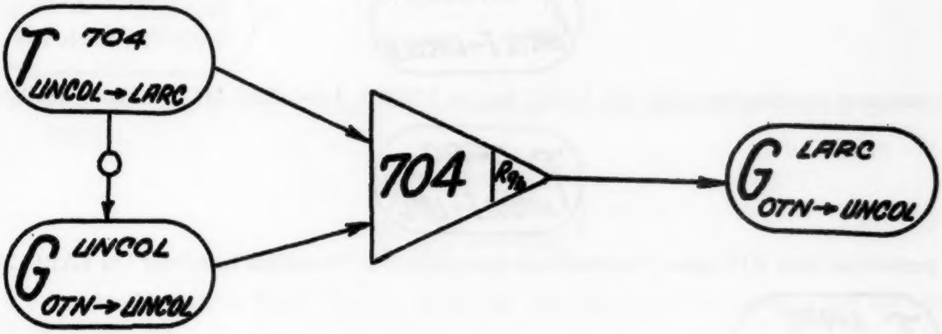
At this point the customer has a file of program decks in LARC ML which permit him to make production runs on the new machine as soon as it is delivered.



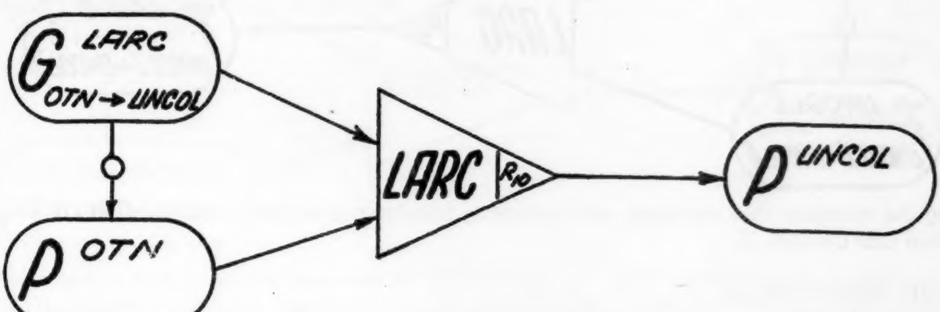
New problems continue to be coded in OMNITRAN.

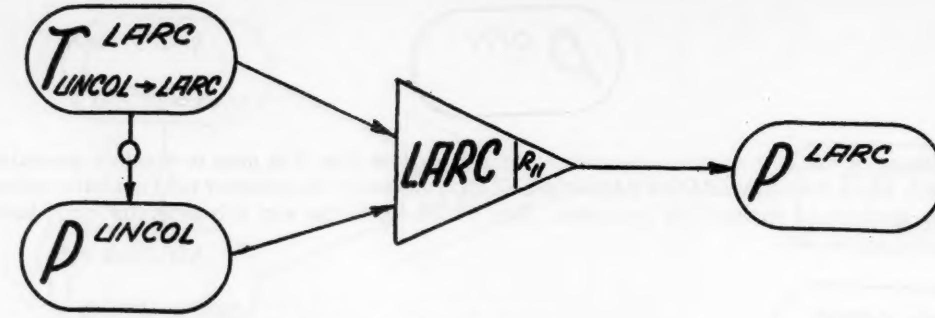
After delivery of the new machine, the customer must perform Run #9a once to obtain a generator in LARC ML which translates OMNITRAN into UNCOL. Actually, the customer need not have waited for the new machine to produce this generator. Run 9b illustrates the way this generator could have been produced on the 704.





The customer organization is now in routine operation on the LARC. For each new problem coded in OMNITRAN, runs 10 and 11 are performed once.



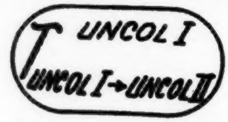


Production runs are accomplished as in Run #8 above.

Any installation can exchange a routine with any other installation, regardless of the machine or POL used, by submitting an UNCOL deck and listing of the routine. The problem description would probably be enhanced if the POL deck and listing were also exchanged.

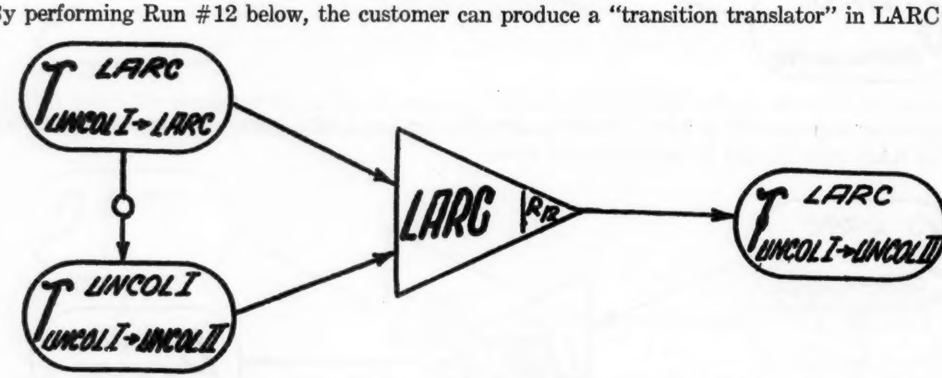
CASE III. Revision of UNCOL

Revisions of UNCOL are not expected to occur very often, possibly only every ten years or so. However, when a change is required, UNCOL has the versatility to permit its own revision. Assume that a new standard, UNCOL II, is to replace the previously used UNCOL I. By considering UNCOL II as an ML, it is possible to write a "transition translator" in UNCOL I.



The customer organization using the LARC has an UNCOL I-to-LARC-ML translator available.

By performing Run #12 below, the customer can produce a "transition translator" in LARC ML.



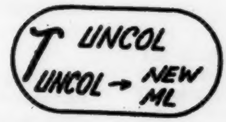
Using the translator thus produced, each generator, translator or routine written in UNCOL I can be translated into UNCOL II.

FUTURE POSSIBILITIES

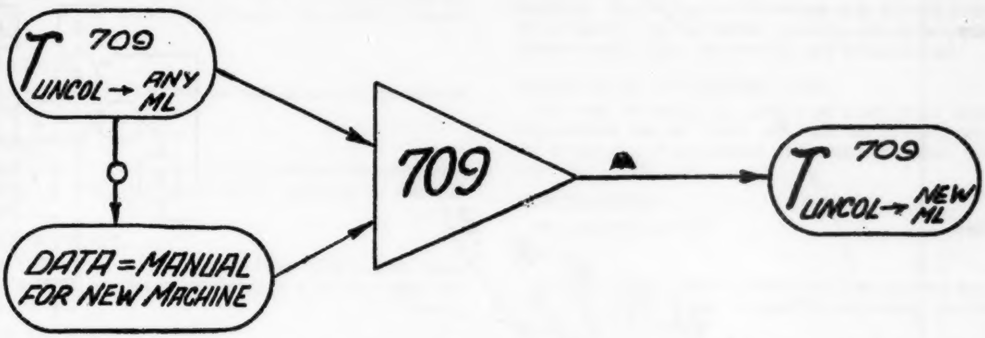
1. In CASE III above, one programmer developed a routine in UNCOL I which permitted all customer

organizations to effect a new standard, UNCOL II, without programming effort. This is a higher degree of "boot-strapping" than hitherto contemplated.

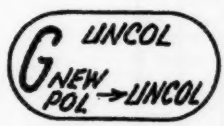
2. Certain areas of programming effort still remain, however.
   a) Each time a new machine is developed, a translator must be written to convert UNCOL to the new ML.



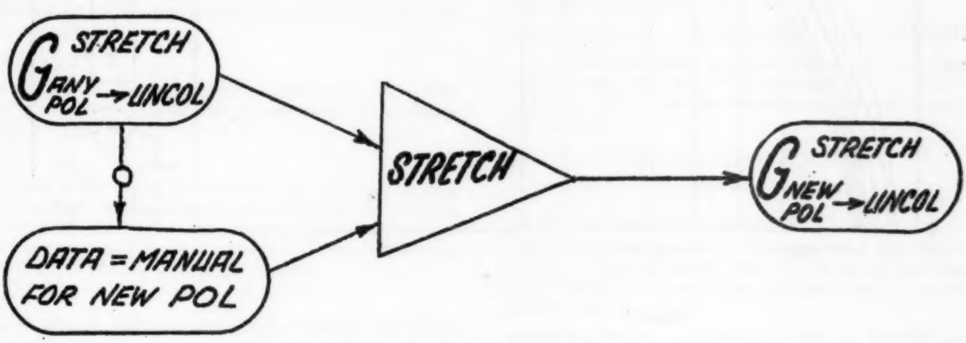
It is altogether possible that a general translator could be written to eliminate the need for programming in this area.



   b) Each time a new POL is developed, a generator must be written to translate the POL into UNCOL.



It is conceptually possible that a "general generator" can be written to eliminate the need for programming in this area.



This would appear to be the maximum in "boot-strapping". Any problem could, in effect, have its own POL tailored to suit its idiosyncrasies, and programming would have advanced to formulating appropriate POL's.

CORRECTION

Figures 1, 2, and 3 published here complete the article "On Programming of Arithmetic Operations" by A. P. Ershov. These figures were inadvertently omitted when the article was originally published in the August 1958 issue of the *Communications*.

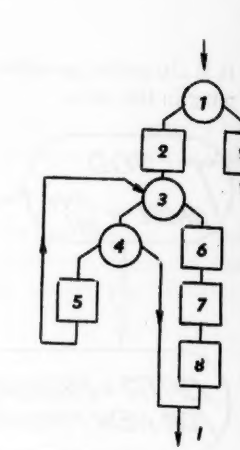


Figure 1

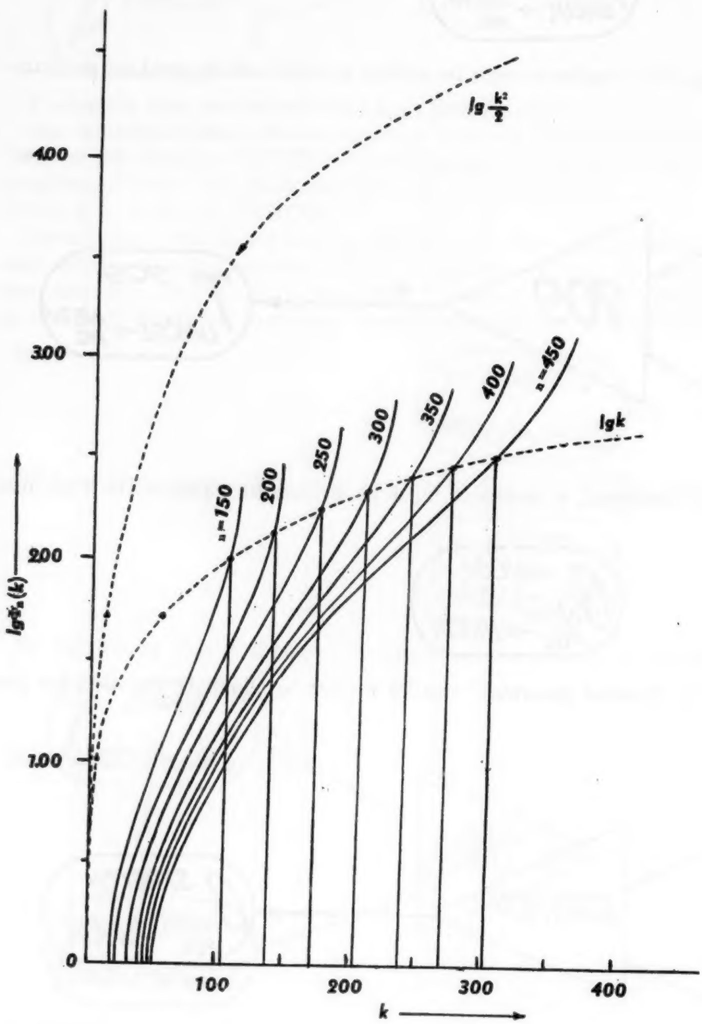


Figure 2

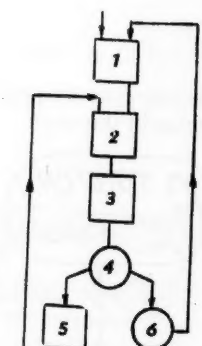


Figure 3

STANDARDS

The following is a continuation of the Standard Department's publication of the "Glossary of Computer Engineering and Programming Terminology" from the Aberdeen Proving Ground, *BRL Report No. 1010*.

The department earnestly solicits all comments concerning the proper use of terms, definitions, ambiguities and unusual meanings and applications.

GATE

a circuit which has the ability to produce an output which is dependent upon a specified type or the co-incidence nature of the input, e.g. an "and" gate has an output pulse when there is time coincidence at all inputs; an "or" gate has an output when any one or any combination of input pulses occur in time coincidence; any gate may contain a number of "inhibits", in which there is no output under any condition of input if there is time coincidence of an inhibit or except signal.

GENERATE

to produce a needed subroutine from parameters and skeletal coding.

GENERATOR

a program for a computer which generates the coding of a problem; a mechanical device which produces an electrical output.

GRID, CONTROL

the electrode of a vacuum tube other than a diode upon which a signal voltage is impressed in order to control the plate current.

HALF-ADDER

a circuit having two output points, S and C, and two input points, A and B, such that the output is related to the input according to the following table:

INPUT		OUTPUT	
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

If A and B are arbitrary input pulses, and S and C are "sum without carry" and carry, respectively, it may be seen that two half-adders, properly connected may be used for performing binary addition.

HARDWARE

the mechanical, magnetic, electronic and electrical devices from which a computer is fabricated; the assembly of material forming a computer.

HEAD

a device which reads, records or erases information in a storage medium, usually a small electromagnet used to read, write or erase information on a magnetic drum or tape or the set of perforating or reading fingers and block assembly for punching or reading holes in paper tape.

HOLD

the function of retaining information in one storage device after transferring it to another device; in contrast to clear.

HUNTING

a continuous attempt on the part of an automatically controlled system to seek a desired equilibrium condition. The system usually contains a standard, a method of determining deviation from standard and a method of influencing the system such that the difference between the standard and the state of the system is brought to zero. See Servomechanism.

IGNORE

a typewriter character indicating that no action whatsoever be taken. (In Teletype or Flexowriter code, all holes punched is an ignore); an instruction requiring non-performance of what normally might be executed; not to be executed.

IMPEDANCE, CHARACTERISTIC

the ratio of voltage to current at every point along a transmission line on which there are no standing waves; the square root of the product of the open and short circuit impedance of the line.

INFORMATION

an aggregation of data.

INPUT

the information which is transferred from external storage into the internal storage; a modifier designating the device performing this function.

INSTRUCTION

a set of characters which defines an operation together with one or more addresses (or no address) and which, as a unit, causes the computer to operate accordingly on the indicated quantities. The term "instruction" is preferable to the terms "command" and "order"; command is reserved for electronic signals; order is reserved for "the order of the characters" (implying sequence) or "the order of the interpolation", etc.

INSTRUCTION, BREAKPOINT

an instruction which, if some specified switch is set, will cause the computer to stop.

INSTRUCTION, BREAKPOINT, CONDITIONAL

a conditional jump instruction which, if some specified switch is set, will cause the computer to stop, after which either the routine may be continued as coded or a jump may be forced.

INSTRUCTION, MULTIPLE-ADDRESS

see code, Multiple-address.

INSTRUCTION, ONE-ADDRESS

an instruction consisting of an operation and exactly one address. The instruction code of a single-address computer may include both zero- and multi-address instructions as special cases.

INSTRUCTION, ONE-PLUS-ONE or THREE-PLUS-ONE ADDRESS

a two- or four-address instruction, respectively, in which one of the addresses always specifies the location of the next instruction to be performed.

INSTRUCTION, TRANSFER

a computer operational step in which a signal or set of signals specifies the location of the next operation to be performed and directs the computer to that operation (or instruction).

INSTRUCTION, TWO, THREE or FOUR ADDRESS

an instruction consisting of an operation and 2, 3, or 4 addresses, respectively.

INSTRUCTION, ZERO-ADDRESS

an instruction specifying an operation in which the location of the operands are defined by the computer code, so that no address need be given explicitly.

INTEGRATOR

a device whose output is proportional to the integral with respect to the input variable.

INTERLACE

to assign successive storage locations to physically separated storage positions, e.g. on a magnetic drum or tape, usually for the express purpose of reducing access time.

ITEM

a set of one or more fields containing related information; a unit of correlated information relating to a single person or object; the contents of a single message.

INTERPRETER

an interpretive routine.

JUMP

an instruction or signal which, conditionally or unconditionally, specifies the location of the next instruction and directs the computer to that instruction. A jump is used to alter the normal sequence control of the computer. Under certain special conditions, a jump may be forced by manual intervention, in other words a transfer of control is made to a specified instruction.

JUMP, CONDITIONAL

an instruction which will cause the proper one of two (or more) addresses to be used in obtaining the next instruction, depending upon some property of one or more numerical expressions or other conditions.

KEY

a group of characters usually forming a field, utilized in the identification or location of an item; a marked lever manually operated for copying a character, e.g. typewriter, paper tape perforator, card punch manual keyboard, digitizer or manual word generator.

LAG

a relative measure of the time delay between two events, states, or mechanisms.

LANGUAGE, MACHINE

information recorded in a form which may be made available to a computer, e.g. punched paper tape may contain information available to a machine, whereas the same information in the form of printed characters on a page is not available to a machine; information which can be sensed by a machine.

LATENCY

in a serial storage system, the access time less the word time, e.g. the time spent waiting for the desired location to appear under the drum heads or at the end of an acoustic tank.

LIBRARY, ROUTINE

an ordered set or collection of standard and proven routines and subroutines by which problems and parts of problems may be solved, usually stored in relative or symbolic coding. (A library may be subdivided into various *volumes*, such as floating decimal, double-precision, or complex, according to the type of arithemetic employed by the subroutines.)

LINE, DELAY

a device capable of causing an energy impulse to be retarded in time from point to point, thus providing a means of storage by circulating intelligence bearing-pulse configurations and patterns. Examples of delay lines are material media such as mercury, in which sonic patterns may be propagated in time; lumped constant electrical lines; co-axial cables, transmission lines and recirculating magnetic drum loops.

LINE-PRINTING

printing an entire line of characters across a page as the paper feeds in one direction past a type bar or cylinder bearing all characters on a single element.

LINE TRANSMISSION

any conductor or systems of conductors used to carry electrical energy from its source to a load.

LOCATION

a unit storage position in the main internal storage, storing one computer word; a storage register.

LOCATION, STORAGE

a storage position holding one computer word, usually designated by a specific address or a specific register.

LOGGER

a devise which automatically records physical processes and events, usually with respect to time.

LOGIC

the science that deals with the canons and criteria of validity in thought and demonstration; the science of the formal principles of reasoning; the basic principles and applications of truth tables, gating, interconnection, etc. required for arithmetical computation in a computer.

LOGIC, SYMBOLIC

exact reasoning about relations using symbols that are efficient in calculation. A branch of this subject known as Boolean algebra has been of considerable assistance in the logical design of computing circuits.

LOGICAL

see operation, logical.

LOOP

the repetition of a group of instructions in a routine.

LOOP, CLOSED

repetition of a group of instructions indefinitely.

MALFUNCTION

a failure in the operation of the hardware of a computer.

MATRIX

in mathematics, an array of quantities in a prescribed form, usually capable of being subject to a mathematical operation by means of an operator or another matrix according to prescribed rules; an array of circuit elements, e.g. diodes, wires, magnetic cores, relays, etc. which are capable of performing a specific function, e.g. conversion from one numerical system to another.

MEMORY

the term "storage" is preferred.

MERGE

to produce a single sequence of items, ordered according to some rule (i.e., arranged in some orderly sequence), from two or more sequences previously ordered according to the same rule, without changing the items in size, structure, or total number. Merging is a special case of collation.

MESSAGE

a group of words, variable in length, transported as a unit; a transported item of information.

MICROSECOND

a millionth part of a second.

MILLISECOND

a thousandth part of a second.

MISTAKE

a human blunder which results in an incorrect instruction in a program or in coding, an incorrect element of information, or an incorrect manual operation.

MNEMONIC

assisting, or intended to assist, memory; of or pertaining to memory; mnemonics is the art of improving the efficiency of the memory (in computers, storage).

MODIFIER

a quantity used to alter the address of an operand, e.g. the cycle index.

MODIFY

to alter in an instruction the address of the operand; to alter a subroutine according to an defined parameter.

MULTIVIBRATOR

a type of relaxation oscillator used for the generation of non-sinusoidal waves in which the output of each of its two tubes is coupled to the input of the other to sustain oscillations.

MULTIVIBRATOR, ASTABLE

a free running type of relaxation oscillator used for the generation of non-sinusoidal waves.

MULTIVIBRATOR, MONOSTABLE

a type of relaxation oscillator used to sustain a trigger pulse for a specified time, since the device assumes another state for a specified length of time at the end of which it returns to its original state, after being pulsed or forced into another state.

NORMALIZE

to adjust the exponent and mantissa of a floating-point result so that the mantissa lies in the prescribed standard (normal) range; standardize.

NOTATION

see "NUMBER-SYSTEM."

NOTATION, BIQUINARY

one of any number of mixed-base notations in which the term n^f in the definition of number system is replaced by the product $\prod_{j=0}^{i-1} m_j$. In the biquinary system, m_j is two for j odd, five for j even; a scale of notation in the base is alternately 2 and 5, e.g. the decimal number 3671 is biquinary 03 11 12 01, the first of each pair of digits counting 0 or 1 units of five and the second counts 0, 1, 2, 3, or 4 units. For comparison, the same number in Roman numerals is MMMDCLXXI. Biquinary notation expresses the representation of numbers by the abacus, and by the two hands and five fingers of man and is used in some computers.

NOTATION, CODED-DECIMAL

decimal notation in which the individual decimal digits are represented by some code.

NOTATION, MIXED-BASE

a number system in which the term n^f in the definition of number-system is replaced by the product $\prod_{j=0}^{i-1} m_j$, e.g. in the biquinary system m_j is two for j odd and five for j even.

NUMBER, BINARY

a numerical value written in the base-two system of notation.

NUMBER, OPERATION

a number indicating the position of an operation or its equivalent subroutine in the sequence forming a problem routine. When a problem is stated in pseudo-code each step is sometimes assigned an operation number.

NUMBER, RANDOM

a set of digits constructed of such a sequence that each successive digit is equally likely to be any of n digits to the base n of the number.

NUMBER-SYSTEM

numerical notation; positional notation; a systematic method for representing numerical quantities in which any quantity is represented approximately by the factors needed to equate it to a sum of multiples of powers of some chosen base n. That is, a number x $= a_q n^q + a_{q-1} n^{q-1} + \cdots + a_1 n + a_0 + a_{-1} n^{-1} + \cdots + a_{-p} n^{-p}$ $= \sum_{i=p}^{i=q} a_i n^i$, with $n < a_i \nless 0$ for all i, is represented by $a_q a_{q-1} \cdots a_1 a_0 a_{-1} \cdots a_{-p}$, with a point to the right of a_0 to identify it. For example, in *decimal notation* familiar to all, in which n equals ten, x = 371.426 represents $3 \cdot 10^2 + 7 \cdot 10^1 + 1 \cdot 10^0 + 4 \cdot 10^{-1} + 2 \cdot 10^{-2} + 6 \cdot 10^{-3}$; in *binary notation*, in which n equals two, x = 1101.01 represents $1 \cdot 2^3 + 1 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0 + 0 \cdot 2^{-1} + 1 \cdot 2^{-2}$, which = 13.75 in decimal notation. In writing numbers, the base is sometimes indicated as a subscript (itself always in decimal notation) whenever there is any doubt about what base is being employed (e.g., $1101 \cdot 11_2 = 13 \cdot 75_{10}$); *Binary, Ternary, Quatenary, Quinary, Octal* (*Octonary*), *Decimal, Duodecimal, Sexadecimal* (*Hexadecimal*) or Duotricenary Notation—notation using the base 2, 3, 4, 8, 10, 12, 16 or 32 respectively.

OCTAL

pertaining to the number base of eight, e.g. in octal notation, octal 214 is 2 times 64 plus 1 times 8 plus 4 times 1 equals decimal 140; octal 214 is binary 010, 001, 100.

ONE-ADDRESS

single address; a system of machine instruction such that each complete instruction explicitly describes one operation and one storage location.

ON-LINE OPERATION

a type of system application in which the input data to the system is fed directly from the measuring devices and

the computer results obtained during the progress of the event, e.g. a computer receives data from wind tunnel measurements during a run, and the computations of dependent variables are performed during the run enabling a change in the conditions so as to produce particularly desirable results.

OPERAND

any one of the quantities entering or arising in an operation. An operand may be an argument, a result, a parameter, or an indication of the location of the next instruction.

OPERATION

a defined action; the action specified by a single computer instruction or pseudo-instruction; an arithmetical, logical, or transferal unit of a problem, usually executed under the direction of a subroutine.

OPERATION, ARITHMETICAL

an operation in which numerical quantities form the elements of the calculation (e.g., addition, subtraction, multiplication, division).

OPERATION, AVERAGE–CALCULATING

a common or typical calculating operation longer than an addition and shorter than a multiplication; often taken as the mean of nine addition and one multiplication time.

OPERATION, COMPLETE

an operation which includes (a) obtaining all operands from storage, (b) performing the operation, (c) returning resulting operands to storage, and (d) obtaining the next instruction.

OPERATION, COMPUTER

the electronic action of hardware resulting from an instruction; in general, computer manipulation required to secure computed results.

OPERATION, FIXED–CYCLE

a type of computer performance whereby a fixed amount of time is allocated to an operation; synchronous or clocked type arrangement within a computer in which events occur as a function of measured time.

OPERATION, LOGICAL

an operation in which logical (yes-or-no) quantities form the elements being operated on (e.g., comparison, extraction). A usual requirement is that the value appearing in a given column of the result shall not depend on the values appearing in more than one given column of each of the arguments.

OPERATION, REAL–TIME, ON–LINE, SIMULATED

the processing of data in synchronism with a physical process in such a fashion that the results of the data-processing are useful to the physical operation.

OPERATION, RED–TAPE

an operation which does not directly contribute to the result; i.e., arithmetical, logical, and transfer operations used in modifying the address section of other instructions in counting cycles, in rearranging data, etc.

OPERATION, SERIAL

the flow of information through a computer in time sequence, using only one digit, word, line or channel at a time. Contrasted with parallel operation.

OPERATION, TRANSFER

an operation which moves information from one storage location or one storage medium to another (e.g., read, record, copy, transmit, exchange). *Transfer* is sometimes taken to refer specifically to movement between different media; *storage* to movement within the same medium.

OPERATION, VARIABLE CYCLE

computer action in which any cycle of action or operation may be of different lengths. This kind of action takes place in an asynchronous computer.

OPERATOR

the person who actually manipulates the computer controls, places information media into the input devices, removes the output, presses the start button, etc.; a mathematical symbol which represents a mathematical process to be performed on an associated function.

OR–CIRCUIT

an electrical or mechanical device which will yield an output signal whenever there are one or more inputs on a multichannel input, e.g. an OR gate is one in which a pulse output occurs whenever one or more inputs are pulsed; forward merging of pulses simultaneously providing reverse isolation.

ORDER

a defined successive arrangement of elements or events. The word order is losing favor as a synonym for instruction, command or operation part due to ambiguity.

OR–OPERATOR

a logical operator which has the property such that if P or Q are two statements, then the statement "P OR Q" is true or false precisely according to the following table of possible combinations:

P	Q	P or Q
False	True	True
True	False	True
True	True	True
False	False	False

OSCILLATIONS, FREE

oscillating currents which continue to flow in a tuned circuit after the impressed voltage has been removed. Their frequency is the resonant frequency of the circuit.

OUTPUT

information transferred from the internal storage of a computer to secondary or external storage; information transferred to any device exterior to the computer.

OUTPUT–BLOCK

a portion of the internal storage reserved primarily for receiving, processing and transmitting data which is to be transferred out.

OVERFLOW

in an arithmetic operation, the generation of a quantity beyond the capacity of the register or location which is to receive the result; over capacity; the information contained in an item of information which is in excess of a given amount.

PACK

to include several brief or minor items of information into one machine item or word by utilizing different sets of digits for the specification of each brief or minor item.

PARALLEL

handled simultaneously in separate facilities; operating on two or more parts of a word or item simultaneously; contrasted with serial.

NEWS AND NOTICES

ACM CHAPTER NEWS

Delaware Valley Chapter:

At the University of Pennsylvania on July 23 the Delaware Valley Chapter heard two presentations in the field of automatic programming. Dr. Grace M. Hopper of Remington Rand Univac described developments in automatic programming up to the present; Charles Katz, also of Remington Rand Univac, described the recent international conference in Zurich, Switzerland, held to consider a universal language for computers.

A current membership drive, spearheaded by Kathryn Feucht of General Electric's Missile Ordnance Systems Department in Philadelphia, is substantially increasing the chapter's membership.

Los Angeles Chapter:

At the September 3 meeting of the Los Angeles ACM Chapter Dr. Morris Rubinoff, Chief Engineer, Philco Corporation, spoke on the topic, "Through Europe Bit by Bit." Dr. Rubinoff, who recently visited a number of European organizations which are active in the computing field, related his observations and interpretations of developments abroad.

Joseph Slap of El-Tronics, Inc., ALWAC Computer Division, who is the new chairman of the Membership Committee reports that membership in the Los Angeles Chapter had increased from 506 on June 1 to 524 by July 28. Other chairmen assuming their new duties on the Chapter Council are Richard Hill of Western Data Processing Center at UCLA, Board of Representatives; Wayne Aamoth of Remington Rand, Program Committee; Frank Wagner of North American Aviation, Data-Link Editor; Richard Utman of Burroughs' ElectroData Division, Publicity; and John Postley of The RAND Corporation, Education.

UNIVERSITY ACTIVITIES AND EDUCATION PROGRAMS

• From the ALWAC Chapter Division, El-Tronics, Inc., we have the following list of university installations of ALWAC computers, dated July 17, 1958:

University	*Location*	*Director*
Oregon State College	Corvalis, Oregon	Dr. A. T. Lonseth
University of British Columbia	Vancouver, B. C.	Dr. T. E. Hull
Institute of Gas Technology	Chicago, Illinois	Duane Kneibes
Chalmers Technical Institute	Gothenburg, Sweden	
Uppsala University	Uppsala, Sweden	Dr. Olov Lowdin

• We have received from Professor W. F. Freiberger of Brown University a more complete statement about the new computing center at Brown. (cf. June, 1958, issue)

Mr. Thomas J. Watson Jr., an alumnus of Brown, and his mother have presented the University with funds for a building to house a computation center. The building is being designed by Philip Johnson of New York, the architect of the Seagram Building. Although the center now has an I.B.M. 650 computer, they hope to install somewhat more elaborate computing machinery (of the order of magnitude of a tape 650 system) when the new building is completed, perhaps in the summer or autumn of next year. They are also members of the New England Colleges and Universities Computing Center of M. I. T. and have been using their I.B.M. 704 computer for problems too large to handle on their present equipment. The Division of Applied Mathematics has for many years been outstanding in the field of solid mechanics, and some of their first and largest computing projects have been in this subject, particularly the plastic theory of structures.

• Worcester Polytechnic Institute, Worcester, Massachusetts, has conducted a two-week Workshop in Digital Computing during September. The purpose of the workshop was "to provide a practical introduction to the principles and techniques of modern automatic digital computing and its applications in engineering and science." For further details write to Dr. Elliott L. Buell.

A three-credit-hour course in Digital Computing, Ma 71, will be offered in the fall term, 1958–1959,

as a part of the Evening Graduate Program. In the spring term, Numerical Analysis, Ma 82, will be offered on the same basis. For details write to Professor F. A. Anderson, Worcester Polytechnic Institute.

- Professor Harvey Cohn, director of Computing Center at Washington University, has been appointed to a professorship at the University of Arizona.
- Dr. R. L. Graves of the Standard Oil Company of Indiana has been appointed assistant professor of applied mathematics in the School of Business, and associate director of the Operations Analysis Laboratory at the University of Chicago.
- A Center for Communication Sciences at the Massachusetts Institute of Technology has been established and is now functioning. Studies of the communication operations of the nervous system and of such machines as computers, as well as methods of communication between the two, are being conducted by a group of scientists and engineers, some of whom have been engaged in such research for several years. The center (using Research Laboratory of Electronics facilities) is under the direction of a steering committee composed of Dr. Jerome E. Wiesner, RLE director; Dr. Claude E. Shannon, Dr. Gordon S. Brown, Dr. Robert M. Fano, Dr. Roman Jakobson and Dr. Walter A. Rosenblith. (Courtesy Datamation).
- A $4,150 endowment fund for the purchase of books in the field of data processing has been established at UCLA by the National Machine Accountants Association, in memory of Bruno Chiappinelli. He was an Association member and UCLA grad. The check was presented in a brief ceremony at the university by NMAA representatives Ralph Singman, Eugene Sheehan and George Taylor. Accepting for UCLA were Dr. Neil H. Jacoby, Dr. George Brown and Gordon Williams. (Courtesy Datamation).
- The University of Chicago has announced plans for its Univac computer that include detailed analyses of the nation's population, weather and economy. The $1,391,600 gift of Remington Rand is being considered for processing of the 1960 census statistics to study population trends, IGY data to determine the functions of the jet stream, and both census and current business figures to develop theories of the U.S. economy. (Courtesy Datamation).

COOPERATIVE PROGRAMMING GROUPS

LGP-30 Electronic Computer Users Group

The first national meeting of the LGP-30 Users Group was held at the Drake Hotel in Chicago July 29-31. Computer users representing over fifty firms, plus personnel from the Royal McBee Corporation of Port Chester, New York (who market the LGP-30) assembled for the purpose of exchanging information of general interest and discussing the various simplified programming methods now available. Among others, the following special programs were analyzed: SPEED—a symbolic compiler; SCOPE—a symbolic optimizing program; the Fort Monmouth symbolic assembly system; and the Royal McBee floating point interpretive system. Routines of general interest, such as solution of partial differential equations, simultaneous equations, fast square root, etc., were studied. An entire day was devoted to discussions within various industry groups—Civil Engineering, Heat Transfer, Optical Design, Chemical Processing and Engineering, Electronic Engineering, Computer Consulting Service, and Missile Ballistics and Aerodynamics—and discussions of the programming of various categories of problems including Matrix Operation and Statistics, Differential Equations, Network Analysis (Hardy Cross, etc.), Business Data Processing, Data Reduction, Interpreters, Symbolic Coding, etc.

Prior to the adjournment of the conference, a Board of Governors was elected to direct the activities of the Users Group for the next year.

ALWAC Users Association

The ALWAC Users Association (AUA) was organized for the purpose of providing a means for the exchange of information concerning techniques and applications for the ALWAC III-E computing system. The current AUA officers are as follows: President, Dr. C. G. Veinott of Reliance Electric and Engineering Company; Vice President, Dr. K. F. Thomson of the Adjutant General's Office; Executive Secretary, Mr. Wayne J. King of ALWAC Computer Division; Chairman, Program Committee, Mr. John Wyman of the U.S. Government; Chairman, By-laws and Constitution Committee, Mr. Ray Joiner of the National Weather Records Center; Chairman, Communications and Publications Committee, Mr. Joseph

Marron of the Adjutant General's Office; Member at Large, Executive Committee, Mr. Byron Horton of Champlin Oil and Refining Company.

AUA has recently issued the first publication of its newsletter, which, it is anticipated, will emphasize news of immediate timeliness, new products, system modifications (local and field), personnel changes, etc.; the technical journal TRADE, however, which will now be published quarterly, stresses ALWAC techniques and ALWAC application reports and studies. Both of these ALWAC publications are edited by Miss Bertha Harper of the Adjutant General's Office.

USE

The 12th meeting of the Univac Scientific Exchange (USE) was held at the St. Francis Hotel in San Francisco, July 30 to August 1, 1958. The Policy Committee met during the first day at the Lockheed Missile Systems Division plant at Palo Alto; all committees met during the next two days at the St. Francis. This meeting was marked by the entry of five new members, bringing the total to 16 organizations. The five new members plan to acquire 1105 computers. Four of them will be installed at various Air Materiel Command (AMC) bases as follows: (1) Gentile Air Force Station, Dayton, Ohio; (2) McClellan Air Force Base, Sacramento, California; (3) Robins Air Force Base, Georgia, and (4) Griffiss Air Force Base, Rome, New York. The fifth new member is the Armour Research Foundation of the Illinois Institute of Technology in Chicago.

A Data Processing Committee was authorized as a new standing committee for subsequent meetings. The other standing committees are: Installations Operation, Program Development, Training, Mathematics, in addition to the governing Policy Committee.

The next USE meetings will be held in El Paso, Texas, December 10–12, 1958, and in Chicago, April 1–3, 1959.

SHARE

The SHARE Executive Board met on Friday, August 1 in Pittsburgh, Pennsylvania. The principal item of business was the firming of the agenda for SHARE Meeting XI in San Francisco on September 10–12. The September meeting was dominated by various ramifications of three major subjects: FORTRAN and its successors, problems arising out of early usage of the 709's, and new developments in IBM equipment.

NEWS ITEMS

• The IBM-STRETCH computer will have 1,024-word, 0.6 microsecond cycle, magnetic core memory modules and 16,000-word, two microsecond cycle, magnetic core memory modules. (The version to be delivered to the Atomic Energy Commission at Los Alamos will have two modules of the 0.6 microsecond cores and six modules of the two microsecond core.) Two "disk control units" will be available with the STRETCH, each unit allowing the control of eight disk memory units which hold one million words each. The units are referenced in 4,096-word blocks, and after access, words are transferred at the rate of 8 microseconds per word. (Los Alamos will get one disk memory.) Four "basic exchanges" will be available with the computer, with each exchange allowing the control of four tape control units to which four 729 tape units (60 kc pulse rate) can be attached. In addition, card readers, card punches and printers can be attached to the basic exchange. Each basic exchange has eight channels, making available a total of 32 channels. A four-stage decoding and control unit will provide a high degree of parallel operation. Three arithmetic processing units, each with its own particular characteristics, will process data simultaneously. The computer will use a 64-bit word and will have operation speeds near the one microsecond level.

• The first Remington Rand UNIVAC 1105 computer was delivered to the Bureau of Census during the week of August 18.

• A new IBM marketing plan, designed to bring office mechanization to small business, has recently been developed. Under this program a basic system which includes two Series 50 machines (a sorter and an accounting machine) and a standard IBM 24 keypunch can be installed for $270 per month. The low-cost Series 50 line includes four re-engineered versions of punched card machines, an 082 sorter, 402

accounting machine, a 514 reproducer, and a 602A calculator. The main differences in the new versions are in volume of output and production rate of records processed.

• ALWAC Computer Division, El-Tronics, Inc., has announced a new plug-in unit tester to be used with the ALWAC III-E. The Universal Tester is designed to be universal in scope and accommodate all possible circuit configurations currently employed or proposed for the future for the ALWAC Computer System.

• The Los Angeles ACM Data-Link reported a quotation from the John Diebold Associates Newsletter as follows, "IBM Corporation is expected momentarily to unveil a full transistorized computer which, because of its building-block design, ranges in power and capacity from just over the IBM card 650 system to beyond that of the IBM 705, Model III. At last reports, executives were still undecided whether to call the new data processing system the "785" or the "7001."

• IBM has recently been contracted by E. I. duPont de Nemours and Company to produce a Special Index Analyzer which will be used for storage and retrieval of technological data at duPont's Newark, Delaware, facility. The system, which will be demonstrated at the International Conference on Scientific Information in Washington, D. C. (November 16–21), is composed of two basic units: An IBM printing card punch for reading and punching cards, and a logical and intermediate storage unit containing both control equipment and an eight-channel paper tape punch and reader. Through the automatic comparison of numerically coded data punched on cards, the index analyzer will make possible ready reference to all filed material relating to a particular subject.

• Pacific Mutual Life Insurance Company in Los Angeles is replacing its UNIVAC I Data Processing System with a UNIVAC II. The latter, with double the memory capacity and twice the speed of its predecessor, will record 1,800,000 policy owner's records on 30 reels of magnetic tape 9 inches in diameter, as opposed to the 60 reels needed with the UNIVAC I. Pacific Mutual, in August, 1955, was the first private industry on the west coast to install a large scale electronic data processing system.

• A Bendix G-15 digital computer will be used in the new U.S. Air Force instrumentation and range safety system at Cooke Air Force Base, California. It will be installed as a part of a $300,000 impact prediction system subcontracted to the Packard Bell Electronic Corporation. The computer will translate flight information for the safety officer who will then be able to determine whether a missile is on its designated course or should be destroyed in flight.

• General Electric Company's Aircraft Gas Turbine Division has developed an IBM 704 program for dynamic production scheduling of a job shop operation. This program schedules approximately 9,000 operations for 200 machine tools, with an average turnover time of 22 days. The GE plan takes into consideration priorities, type and amount of overtime allowed, the effect of sequential operations, and holidays. The program, which will schedule operations for up to one year in advance, requires about 25 minutes of running time on the IBM 704. Future plans call for extension of this program to optimization of machine loading, development of input data for cost accounting, etc.

• A Remington Rand Univac File-Computer is to be installed at Rome Air Force Depot. It will be used in processing the huge volume of statistical and record data on ground radar and other critical communications equipment which the Depot handles in connection with its function of installing and engineering new and revised systems (for early warning lines, ground control approach, search radar, missile tracking, and tropospheric and ionospheric scatter communications) and in storing and issuing over 100,000 stock items of electronic equipment for the entire Air Force.

• The IBM 305 RAMAC is being used extensively in the Coast Guard's new program for expediting search and rescue operations. This program, known as AMVER (Atlantic Merchant Vessel Report System), divides the North Atlantic Maritime Region into two search and rescue areas. Ships report their position, speed and course when entering the Maritime Region, when crossing from one search and rescue area to the other, and upon leaving the Region. This information is punched into cards and fed into the 305 for processing and storage. Once a day, the machine automatically computes the dead reckoning position of each ship to update all ship position records. In case of emergency, the latitude and longitude of the ship in distress will be entered into the computer which will then automatically determine which vessels are in the immediate and surrounding areas so the Coast Guard can advise the ships best situated and adapted for search and rescue operations.

• A new technique designed for a large-scale (704) computing system, developed by Dr. D. J. Rogers of the New York Botanical Gardens and Dr. T. T. Tanimoto of the Mathematics and Applications Department of IBM, classifies plants automatically according to their individual characteristics. An exacting description of the plant (up to 100 characteristics including size, color, root structure, and leaf structure) is recorded in punched cards which the computer digests. The plant is then automatically classified into a natural group or cluster, with each cluster being determined by the overall physical similarities of the plants that comprise it. Because the computer analyzes such a great number of characteristics, it can detect subtle similarities linking plants to certain groups which otherwise might not be apparent even to a skilled botanist. The new plant classification technique can also be applied to other areas. For example, in the medical field, diseases might be automatically classified on the basis of similarity of various measurable symptoms.

• An IBM tape 650 was featured in the Atomic Energy Commission exhibit at the Atoms for Peace Conference, September 1–14. Included among the unusual applications processed on the computer were the following: calculations to effect controlled thermonuclear reactions at the extremely high temperatures of the fusion process; the analysis of various radioactive isotopes; summaries of the amount of radiation present within the human body; calculations involved in designing and controlling industrial reactors; and industrial area radiation monitoring calculations.

• Beginning in September, the ALWAC III-E Service Center in Hawthorne, California, will make available a complete demonstration of data processing activities encountered in supermarket management. The demonstration, though designed for supermarkets, also will apply to many different types of businesses and will show how the many facets of commercial data processing are profitably accommodated on a low cost computer. Soon after the September and October series of local demonstrations, the identical routine, variable with respect to any given business, will be shown in New York, Cleveland, San Francisco, and points in Canada.

• The U.S. Air Force Air Materiel Command and Remington Rand have jointly developed a method for using a limited vocabulary of English verbs to instruct business-type computers. The new method, known as the Air Materiel Command Automatic Compiler (AIMACO) will initially use 30 English verbs, and has the flexibility of enlargement to include additional verbs as circumstances dictate. A large-scale computer is used to convert English to machine language for itself and for other computer makes and models as well. The basis for the new system has already been machine tested, is now in successful limited use, and will be in general operation at major AMC facilities by the end of 1958.

• The ALWAC Computer Division has announced that a completely automatic department store merchandise control system is now available. The system is composed of NCR Sales-Tronic cash registers, which automatically prepare punched paper tape records of all retail transactions, and the ALWAC III-E Electronic Data Processing System which accepts the recorded transactions from punched paper tape and automatically performs the required processing. The major feature of the system is that a complete sales record of 30,000 transactions or less from one or several cash registers may be accommodated by the ALWAC III-E without any physical sorting and will provide, among other functions, a complete unit and class merchandise control, buyers reports, activity analysis, as well as the ordinary commercial operations of billing, payroll, payables, and others.

• Dr. David M. Young, formerly Manager of the Mathematical Analysis Department of the Computation and Data Reduction Center at Space Technology Laboratories in Los Angeles, California, recently accepted a position as Professor of Mathematics and Director of the Computation Center at the University of Texas in Austin, Texas. The Computation Center utilizes an IBM 650 installation which has been newly established in connection with the university's expanding computing and numerical analysis program.

• Emil D. Schell, who has been Director of the New York Research Office af Remington Rand, has joined IBM Research as an advisory mathematician to work on the theory of machine organization.

• Benjamin Mittman, formerly Scientific Representative at Remington Rand Univac, has joined Ar-

mour Research Foundation of Illinois Institute of Technology, Chicago, as a research mathematician.

• Dr. Jack Moshman, Director of the Mathematical and Statistical Services Division of the Corporation for Economic and Industrial Research (CEIR), recently announced the elevation of Harold E. Fassberg to the position of Deputy Director of the Division. Mr. Fassberg, since joining CEIR three years ago, has specialized in the application of mathematical techniques in Operations Research, particularly to transportation problems.

• Pasqual A. DonVito, previously with The RAND Corporation in Los Angeles, Kenneth W. Webb, formerly with the Navy Bureau of Aeronautics, and Robert Patrick, formerly with General Motors have recently joined CEIR.

• Dr. Herbert F. Mitchell, Jr., formerly Director of UNIVAC Applications for Remington Rand in Los Angeles, has recently been appointed Director of Management Services in Remington Rand's New York office.

• Ascher Opler and Norma Baird recently resigned from the Dow Chemical Company to accept positions on the staff of Computer Usage Company, 18 East 41st Street, New York 17, New York.

• Dr. Eugene M. Grabbe, senior staff consultant on automation, The Ramo-Wooldridge Corporation, was one of the twelve members of the American Automatic Control Council who toured factories and academic institutes in Russia August 18–September 1 as guests of the Institute of Automatic and Remote Control, U.S.S.R. The tour included visits to such automated facilities as a watch factory in Moscow, instrument plant in L'vov, as well as the Automatics and Telemechanics Institute, Academy of Sciences, of the U.S.S.R. in Moscow. A team of Russian experts visited similar plants in this country earlier this year.

• New technical staff members at Philco Corporation's Western Development Laboratories in Palo Alto include: Paul Atkinson, Director of Human Factors Group; Wade H. Cone, Manager of Field Operations; Royal V. Howard, Manager of WDL Operations in Hawaii; John C. Keyes, Manager of Program Planning and Integration; and Jack H. Pfeiffer, Manager of Mechanical Design and Services.

• Dr. Howard T. Engstrom, formerly Deputy Director of the National Security Agency, has recently returned to Remington Rand Univac Division of Sperry Rand Corporation as Vice President and Director of Marketing of Univac Scientific and military systems. Dr. Engstrom was a founder of Engineering Research Associates which was acquired by Remington Rand in 1952.

• Duane Bickel of Lockheed has transferred to the Missile System Division and will become Supervisor of the Data Problems Group at the new 709 installation at Sunnyvale, California.

• Daniel D. McCracken has recently joined the staff of the Atomic Energy Commission Computing Center of the Institute of Mathematical Sciences at New York University.

• Graham Tyson is now Senior Applications Engineer for data handling systems at Telemeter Magnetics, Inc., Los Angeles, California.

• Donald Wall of IBM has been assigned to the Applied Programming Group at World Headquarters in New York City. Edgar Smith of IBM, Santa Monica, California, will assume his former responsibilities as Applied Programming representative to the Western Data Processing Center at UCLA.

• Marjorie A. Owens, formerly with Missile Ordnance and Systems Department, General Electric Company, has accepted a position as programming consultant with the Crosley Division of the Avco Manufacturing Company, Cincinnati, Ohio. She is a member of the Delaware Valley Chapter of ACM.

• Irvin Marshall is now associated with the Numerical Analysis Division of the RAND Corporation.

• Mr. J. C. McCall of the University of Illinois has accepted a position as General Manager of the Midwest Computer Service, Inc., Decatur, Illinois.

• Recent additions to the staff at Space Technology Laboratories in Los Angeles, California, include Dr. Lincoln H. Turner, formerly of Purdue University; Dr. J. D. Riley, formerly of Iowa State College; Thomas Sanborn, formerly with Douglas Aircraft Corporation; J. Arthur Conley, Jr., from Land-Air; Janez Bourdeaux; William Morsch, from De Vries and Company; and Charles Thoma, from the U.S. Air Force installation at Johnstown, Pennsylvania.

• New additions to the staff of ElectroData Division of Burroughs Corporation in Pasadena, California, include Paul Colen—Market Department; Milton Stone—Sales Department; Robert Mallett, formerly

with North American Aviation—Applied Programming Section; Richard Senseman, formerly of the Boston Sperry-Rand Univac office—Publications and Training Section; and Carl Powers, formerly with the Remington Rand Univac New York Training Department—Publications and Training Section. John McVey is transferring from the Pasadena Publications and Training Section to the Los Angeles District Office where he will become a Sales Technical Representative.

• Joseph A. Resca has been named New York District Sales Manager for the Burroughs Corporation's ElectroData Division. Mr. Resca will be in charge of Burroughs E101, 205 and 220 computers and electronic data processing systems in greater metropolitan New York.

• A complete English translation of the leading Soviet automatic control journal AVTOMATIKA I TELEMEKHANIKA is now available at very low cost subscription rates. Distribution will be through The Instrument Society of America. General subscription rates are $30 for one year (12 issues) or $3.50 for a single issue.

• A new bi-monthly magazine, "*Machine Accounting and Data Processing*—The Magazine of Automatic Office Operations" will make its first appearance in October, 1958. The publication will contain information pertinent to punched-card and punched-tape equipment and methods, business computers and systems, and procedures related to automation in the office. It will also include feasibility studies, operations research, and other planning data. The magazine will be published by Gille Associates, Inc., 956 Maccabees Building, Detroit, Michigan. Editorial activity will be handled by Eugene F. Murphy. News releases may be forwarded to Mr. Murphy at 52 Gramercy Park North, New York 10, New York.

• New reports available from Remington Rand describe features and uses of the Univac File Computer Data Automation System, Model 1 (U 1562); how to program the Univac File Computer—available to users of the Univac File Computer or for reference on a loan basis (U 1474); and how a bank (the Western Saving Fund Society of Philadelphia) increased its total transactions 45 per cent in five years using a Univac computer (UC-877). Those interested in obtaining any of these reports may contact any branch office or write Remington Rand Division of Sperry Rand Corporation, 315 Fourth Avenue, New York 10, New York.

• A complete operational and programming manual for the advanced ALWAC III-E Computing System for Numerical Control (NUCOP) is now available from any ALWAC regional office or at the home office of the El-Tronics, Inc., ALWAC Computer Division in Hawthorne, California. NUCOP, which has successfully been employed in cutting the AIA Testpiece (consisting of various 2 and 3 dimensional profiles and other complex forms), is designed to enable the part programmer to create automatically a punched-tape which will drive a numerically controlled machine tool. The NUCOP technique takes advantage of continuous paths in that only three types of profiles are ever considered: A straight line, a circle, or any other curve type. This technique completely obviates the heretofore tedious operation of point by point computation, thus reducing tape preparation time to a virtual minimum. The NUCOP system is currently being profitably employed on the ALWAC III-E installation of Menasco Manufacturing Company in Burbank, California. Courses are offered by ALWAC in the use of NUCOP.

• Seventy-two people attended the first meeting of a newly organized computer group in Washington, D. C. Dr. R. W. Hamming, National ACM President, spoke on "Ideal Computers of the Future." The group voted to petition ACM for Chapter status, and a committee to prepare bylaws acceptable to ACM was appointed. Pro tem officers were elected as follows: Chairman, Lowell McClung, of Johns Hopkins University Applied Physics Laboratory; Vice Chairman, William Orchard-Hayes of Corporation for Economic and Industrial Research; and Secretary, Saul Gass of International Business Machines Corporation.

• The next meeting of the Mid-Continent Computer Club (MC^2) will be held in Chicago on Friday, October 3, 1958 at Stouffer's Restaurant at 26 West Madison. The speaker for the evening will be Dr. Preston C. Hammer, Director, Numerical Analysis Laboratory, University of Wisconsin. The title of his talk will be "Numerical Analysis, Information, and Computing."

• At the August 15 meeting of the Digital Computers Association in Los Angeles Stuart Dreyfus of The RAND Corporation spoke of "Dynamic Programming" as a technique for solving multi-stage decision process problems. Mr. Dreyfus pointed out that the use of dynamic programming may eliminate the

multiple unnecessary path whichs one may take in arriving at the solution of a problem.

• Burroughs Corporation ElectroData Division has established two new district sales offices in Atlanta, Georgia, and Denver, Colorado. It now has 22 district and regional sales headquarters.

• The Ramo-Wooldridge Corporation has been awarded a five-year $13,500,000 contract for installation and operation of an automatic data processing system at the Army Electronic Proving Ground, Fort Hauchuca, Arizona. Ramo-Wooldridge will provide technical assistance to conduct field testing of automatic data processing systems for operational suitability and acceptance.

• Expansion of Datamatic, the data-processing division of Minneapolis-Honeywell Regulator Company, has resulted in the opening of a Washington D. C., sales office, at 4926 Wisconsin Avenue, N.W. Robert F. Anderson, assistant manager of southeastern sales, is in charge, with Fillmore Dobbs as his assistant.

• Marc Shiowitz and Associates, digital computer consultants and engineers, located in Gardena, California, have incorporated as Marc Shiowitz and Associates, Inc. The firm provides computer application and engineering services to many prime contractors responsible for design and development of new weapons systems. It also furnishes programming, application studies, and machine evaluation service to business computer users.

• The Congreso Internacional de Automatica is being held in Madrid, Spain, on October 13–18. This Congress, organized by the "Instituto de Electricidad y Automatica" and sponsored by the "Consejo Superior de Investigaciones Cientificas" together with Spanish and foreign industrial concerns, will assemble a group of scientists from various parts of the world to discuss the following topics: Linear and Non Linear Automations; Switching Theory; Research and Development of Electronic Computers; New Computer Components; Logical Design Techniques for Computers; Machine Tools with Numerical and Analogical Command; Automation of Industrial Plants; Data Processing; and Human and Economic Aspects of Automation. A system of simultaneous translations in German, French, English, Russian and Spanish will be utilized, and a book containing the papers read at the symposium will be published sometime after the ending of the conference.

COMING EVENTS

• 14th Annual National Electronics Conference
  October 13–15, 1958; Hotel Sherman, Chicago, Illinois
  Sponsor: AIEE, Illinois Institute of Technology, IRE, Northwestern University, University of Illinois
  Contact: NEC, Inc., 84 East Randolph Street, Chicago, Illinois

• Congreso Internacional de Automatica
  October 13–18, 1958; Madrid, Spain
  Sponsor: Consejo Superior de Investigaciones Científicas
  Organized by: Instituto de Electricidad y Automatica
  Contact: Professor J. G. Santesmases, Institute de Electricidad y Automatica, Facultad de Ciencias, Cuidad Universitaria, Madrid, España

• Meeting on Hydrodynamics
  October 16–18, 1958; Los Alamos Scientific Labs, Los Alamos, New Mexico
  Sponsor: Los Alamos Scientific Labs
  Contact: Dr. G. N. White, Los Alamos Scientific Labs

• UNIVAC Users' Conference
  October 20–21, 1958; John Hancock Mutual Life Insurance Company, Boston, Massachusetts

• National Business Show
  October 20–24, 1958; Coliseum, New York City, New York
  Contact: R. Lang, Managing Director, 530 Fifth Avenue, New York 36

• 1958 National Simulation Conference
  October 23–25, 1958; Statler-Hilton Hotel, Dallas, Texas
  Sponsors: IRE-PGEC and Dallas Section of IRE
  Contact: J. E. Howard, 2100 Menefee Drive, Arlington, Texas

- American Mathematical Society Meeting
  October 25, 1958; Princeton University, Princeton, New Jersey
- Fifth Annual Computer Applications Symposium
  October 29–30, 1958; Morrison Hotel, Chicago, Illinois
  Sponsor: Armour Research Foundation, Illinois Institute of Technology
  Contact: Armour Research Foundation, 35 West 33 Street, Technology Center, Chicago 16, Illinois
- 4th Electronic Business Systems Conference
  October 30–31, 1958; Olympic Hotel, Seattle, Washington
  Sponsor: Western Division, NMAA
  Contact: E. B. S. Conference, NMAA, Western Division, P. O. Box 134, Seattle 11, Washington
- International Conference on Scientific Information
  November 16–21, 1958; Mayflower Hotel, Washington, D. C
  Sponsor: National Academy of Sciences, National Research Council, National Science Foundation, American Documentation Institute
  Contact: Secretariat, International Conference on Scientific Information, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington 25, D. C.
- American Mathematical Society Meetings
  November 21–22, 1958; Pomona, California
  and
  November 28–29, 1958; Northwestern University, Evanston, Illinois
  and
  November 28–29, 1958; Durham, North Carolina
- Computer Exhibition and Business Symposium
  November 28–December 4, 1958; London, England
  Contact: Exhibition Organizer, 11/13 Dowgate Hill, London E.C. 4, England
- Eastern Joint Computer Conference
  December 3–5, 1958; Bellevue-Stratford Hotel, Philadelphia, Pennsylvania
  Contact: John Broomall, Dev. Engr., Burroughs Corporation, Research Center, Paoli, Pennsylvania (General Chairman); F. M. Verzuh, Asst. Director, Computation Center, M.I.T., Cambridge, Massachusetts (Technical Program Chairman)
- USE Meeting
  December 10–12, 1958; El Paso, Texas
- American Mathematical Society—65th Annual Meeting
  January 20–22, 1959; University of Pennsylvania, Philadelphia, Pa.
- Western Joint Computer Conference
  March 3–5, 1959; Fairmont Hotel, San Francisco, California
  Contact: M. L. Lesser, IBM Research Lab, San Jose, California
- USE Meeting
  April 1–3, 1959; Chicago, Illinois
- Joint Meeting of Institute of Mathematical Statistics (Central Region) and the Association for Computing Machinery
  April 2–4, 1959; Case Institute of Technology, Cleveland, Ohio
  Contact for IMS: Martin B. Wilk, Bell Telephone Laboratories, Murray Hill, New Jersey
  Contact for ACM: Daniel Teichroew, National Cash Register, Dayton 9, Ohio
- 1959 Electronic Components Conference, "New Concepts for Space Age"
  May 6–8, 1959; Benjamin Franklin Hotel, Chestnut Street at 9th, Philadelphia, Pennsylvania
  Sponsors: AIEE, IRE, EIA, WCEMA
- First International Conference on Information Processing (ICIP)
  June 13–21, 1959; Europe
  Contact for U.S. Committee of ICIP: I. L. Auerbach, Auerbach Electronics Corporation, 109 North Essex, Narberth, Pennsylvania

Sponsor: UNESCO

- 1959 ACM National Conference
  Summer, 1959; Massachusetts Institute of Technology, Cambridge, Mass.
  Contact: F. Verzuh, M.I.T.
- American Mathematical Society Meeting
  Summer, 1959; Salt Lake City, Utah
  November, 1959; Detroit, Michigan
- Eastern Joint Computer Conference
  1959; Boston, Massachusetts
- Second Interkama—International Congress and Exhibition for Measuring Techniques and Automation
  October 19–26, 1960

NOTICES

OF CHANGE OF ADDRESS

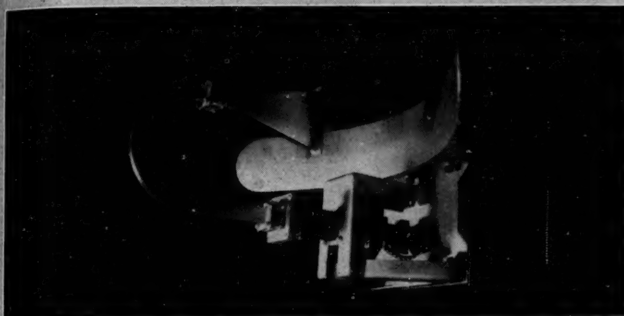
should be sent to the

ASSOCIATION FOR COMPUTING MACHINERY

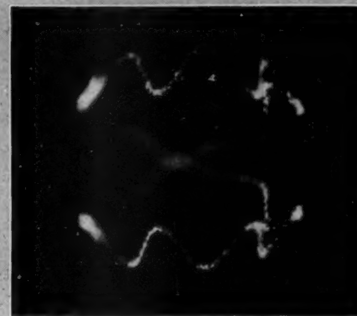
2 East Sixty-Third Street
New York 21, New York.

One month's notice is required in order to guarantee delivery of periodicals and other mailings to the new address.

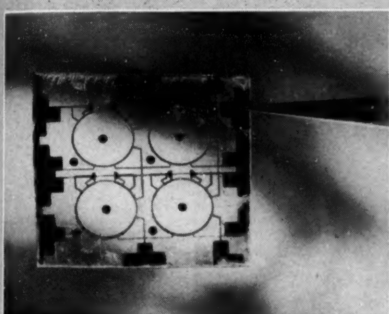
Please include previous address



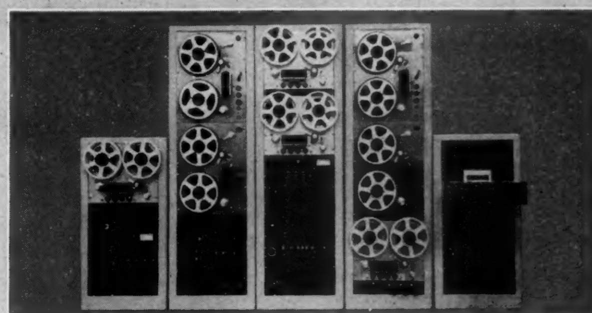
Horn fed parabolic reflector antenna for airborne applications.



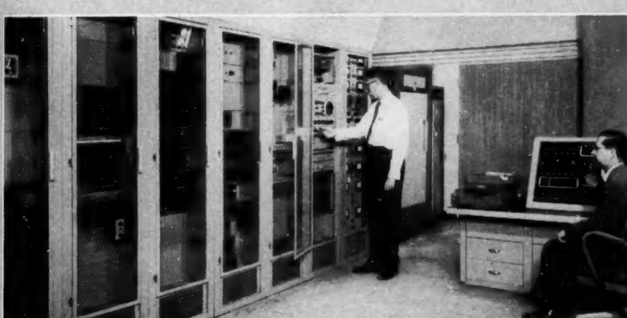
Charged aluminum particle suspended and controlled in a vacuum chamber by an oscillating electric field.



The Persistor gives promise of cryogenic computer memories with a capacity of 1,000,000 bits per cubic foot and access times of 1/30 microsecond.



Ground based data handling equipment for processing analog and digital reconnaissance information.



Data conversion system for digitizing and processing telemetered missile test data.

Electron micrograph of impact produced on aluminum coated glass by a 1 micron diameter particle traveling at 7,000 feet per second.

Pictorial **PROGRESS REPORT**

The photographs above illustrate some of the recent research, development, and manufacturing activities at Ramo-Wooldridge. Work is in progress on a wide variety of projects, and positions are available for scientists and engineers in the following fields:

- Digital Computers and Control Systems
- Communications and Navigation Systems
- Guided Missile Research and Development
- Infrared Systems
- Electronic Countermeasures
- Electronic Instrumentation and Test Equipment
- Basic Electronic and Aeronautical Research

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